Gartner Lee
Associates Limited

PORTAGE LA PRAIRIE LANDFILL
HYDROGEOLOGICAL STUDY

PREPARED BY:
GARTNER LEE ASSOCIATES LIMITED

PROJECT 84-96

MARCH 1985

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April 11, 1985.

Mr. Adolf Anders,
Senior Project Engineer,
Environmental Protection Service,
Environment Canada,
800 - 275 Portage Ave.,
Winnipeg, Manitoba.
R3B 2B3

Dear Mr. Anders:

Re: Portage La Prairie Landfill Hydrogeological Study, GLAL 84-96

We respectfully submit our report on the above noted study. The report describes the Portage La Prairie landfill site's geology, shallow hydrogeology and hydrochemistry based on our airphoto interpretation and field studies. The extent of ground water contamination is discussed as well as recommendations for future monitoring considerations.

We trust that this study meets with your requirements and needs. We would like to take this opportunity to thank Environment Canada and the Manitoba Department of Environment and Workplace Safety and Health for involving our company in this most interesting study.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

P.K. Lee, M.A.Sc., P.Eng.,
Consulting Engineering Geologist.

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STEERING COMMITTEE MEMBERS

Mr. A. Anders, Senior Project Engineer, Environmental Protection Service, Environment Canada.

Mr. D. Thompson, Head, Waste Management, Manitoba Department of Environment and Workplace Safety and Health.

Mr. C. Lee, Environmental Engineer, Manitoba Department of Environment and Workplace Safety and Health

1.0 EXECUTIVE SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1.1 PURPOSE AND SCOPE

On September 27th, 1984 Gartner Lee Associates Limited was retained by the Department of Supply and Services, for Environment Canada and the Manitoba Department of Environment, to undertake a hydrogeological study of the Portage La Prairie landfill. The objective of this study was to determine the extent of ground water contamination. This was to be addressed by defining the ground water flow directions and velocities. The study was to implement a surface geophysical program, a test well installation program and a ground water sampling program to define the extent of ground water contamination.

1.2 CONCLUSIONS AND RECOMMENDATIONS

The results of the hydrogeological, geochemical and geophysical studies all show that contaminants are migrating in a southerly direction away from the landfill in a shallow unconfined sand aquifer. The ground water velocity in this formation is approximately 130 metres/year. A number of domestic wells downgradient from the landfill have been impacted by leachate. Ground water quality impairment was defined by elevated concentrations of chloride, bicarbonate, iron, sulphate and alkalinity resulting from the degradation and leaching processes in the landfill. In addition, a number of wells downgradient have also been impacted by arsenic. This may be attributed to the landfill where arsenic is reported to have been applied to the refuse in the late 1970's as part of a rodent control program.

The landfill has been in operation for approximately 50 years. The potential therefore exists for contaminants to be discharging to the Assiniboine River, approximately 1200 m south of the landfill. Contaminants discharging to the Assiniboine River will probably be of low concentrations owing to dilution, dispersion and the natural attenuating properties of the soils over this distance.

A ground water mound has likely developed in the 10 to 15 m high landfill. It appears that contaminants are also migrating in a northerly direction caused by radial flow from the ground water mound. The extent of the northerly contaminant movement and the effect of the ground water mound have yet to be defined.

The geophysical survey identified the major concentrations of a contaminant plume migrating in a southerly direction down a meander scar of the Assiniboine River.

The area that presently appears to be affected by landfill leachate is shown in Figure E1. In this area some wells are presently impacted with landfill leachate and others may be affected in the future. This is based on the present contaminant migration pattern and the effects of domestic wells pumping ground water from the shallow sand aquifer. The definition of the affected area has been established utilizing the results of geological, hydrogeological, geochemical and geophysical surveys.

Based on the above conclusions we recommend:

(1) The ground water from domestic and test wells be resampled in the spring of 1985. The water levels in the test wells should also be measured. At present there is only one set of water level and geochemical data for the test wells.

(2) The extent of the northern contaminant plume be more fully defined. The installation of a further five test wells should serve this purpose. Water level measurements and geochemical sampling of these wells should be incorporated into a biannual ground water monitoring program. The monitoring program will allow the regulatory agency to assess the lateral extent of ground water contamination as a function of time.

(3) Considerations should be given to monitoring the impact of leachate on the Assiniboine River.

(4) The Canadian Drinking Water Standards are exceeded for some chemical parameters at several residences downgradient from the landfill. These water supplies should not be used for drinking if further chemical analyses confirm the present data.

(5) Properly graded, low permeability cover material should be placed on the landfill to decrease infiltration. This will reduce leachate volumes.

2.0 INTRODUCTION

2.1 LOCATION

The Portage La Prairie landfill site is located within the southern portion of the City (Figure 1). It is located just north of the Assiniboine River and approximately 1 km southwest of the Trans-Canada Highway and Provincial Highway 240 intersection.

2.2 BACKGROUND INFORMATION

The Portage La Prairie landfill site has been in operation since the 1930s and is located within the meander belt of the Assiniboine River. The disposal of municipal refuse has filled the northern section of George Lake, an oxbow lake formed by the erosive action of the Assiniboine River. The landfill is presently 10 m to 15 m above grade and is approximately 0.06 km^2 in surface area.

A preliminary study conducted in 1983 by Underwood McLellan Limited determined several wells in the vicinity of the landfill were contaminated with leachate. Ground water sampled from wells downgradient of the landfill contained elevated concentrations of arsenic, iron, manganese, chloride, sodium and other parameters. High arsenic concentrations in the ground water are believed to be associated with past applications of rodent control poisons at the landfill.

The objective of this study was to determine the extent of ground water contamination. This was to be addressed by defining the ground water flow directions and velocities. The study was to implement a surface geophysical program, a test well installation program, and a ground water

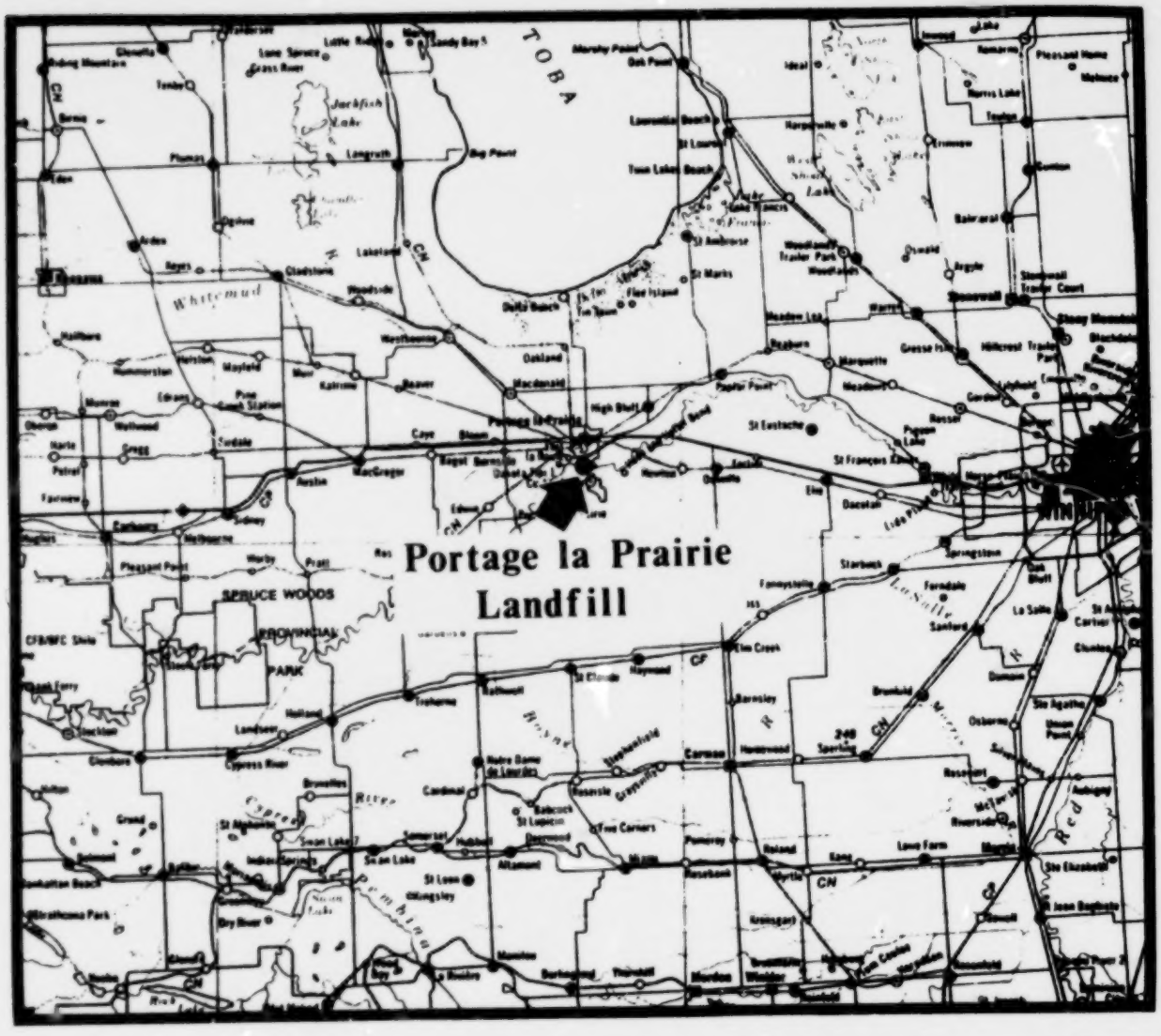

Figure 1

LOCATION MAP

N

Scale 1:1,000,000

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sampling program to assist in the definition of the extent of ground water contamination.

2.3 METHODOLOGY

2.3.1 MEETINGS AND CORRESPONDENCE

Continual liaison was maintained throughout the study between Steering Committee members and Mr. D. Slaine of Gartner Lee Associates Limited. Informal meetings took place throughout the field investigation component of the study (October 22, November 20, 1984).

2.3.2 SURFACE GEOPHYSICAL SURVEYS

Surface geophysical surveys were implemented in the first phase of this hydrogeological study to optimize locations for installing test wells. The site was analysed, based on the known geology of the site, with a geophysical predictive model (GEOTAM) to assist in the selection of the best suited electromagnetic or resistivity equipment. Well log data supplied by the Department of Environment and Workplace Safety and Health was used to create a geoelectric section for modelling purposes as described by Greenhouse and Slaine (1983). This sensitivity analysis showed the Geonics EM-31 would provide the best resolution of mapping contaminant-induced conductivity changes in the ground water.

On October 8, 9 and 10, 1984 the terrain conductivity of lands surrounding the landfill was mapped using the Geonics EM-31. This electromagnetic device measures the

apparent conductivity of the earth to depths of 5 m. Further description of the operating principles of this instrument are explained by McNeill (1980). A total of 370 readings were taken and all data were referenced to enlarged aerial photograph maps.

VLF resistivity and geoelectric resistivity soundings were also used to augment the terrain conductivity survey. The Geonics EM-16R was used for the VLF resistivity survey. This device has at a depth of exploration of 25 m to 40m. The Bison 2350 Resistivity Meter was used for the resistivity soundings. The Wenner electrode configuration was used giving a vertical geoelectric cross-section of approximately 30 m.

All geophysical data were compiled and analysed the week following the field investigation. The resistivity sounding results were utilized to obtain a better definition of subsurface conditions at the site. The VLF resistivity and terrain conductivity survey results were used to define electrical conductivity anomalies in the vicinity of the landfill. The results of all three geophysical surveys were used in the decision making process of where to locate test wells in order to obtain ground water samples.

2.3.3. TEST WELL INSTALLATION PROGRAM

The subsurface investigation of the soils surrounding the Portage La Prairie landfill began on October 22, 1984 and was completed on October 25, 1984. The test wells were installed with a backhoe and water-jet method. The unsaturated soil was excavated with the backhoe until saturated sand was located. The test wells, constructed of Schedule 80, 38 mm I.D. PVC tubing, were equipped with

a one-way PVC check valve. Water was injected into the top of the tubing which displaced sand at its tip. This allowed the well to be "water-jetted" to depth until the tip came in contact with fine-grained material (assumed clay).

A total of nine test wells were installed by this technique. The electrical conductivity of the clean, injected water was measured prior to injection. All wells were surveyed with a level to determine relative ground water elevations.

2.3.4 GEOCHEMISTRY

The ground water from the test wells was sampled on November 20 and 21, 1984, one month after the test wells were installed. This time period was allowed to let the injected clean water migrate downgradient from the wells.

Each well was equipped with dedicated 6 mm I.D. polyethylene tubing to eliminate cross-contamination of ground water samples. The sample water was drawn from the well with a manually operated vacuum pump that attached to the dedicated tubing. A total of eight to ten well volumes were removed from the well prior to sampling to ensure formation water was sampled. The electrical conductivity of this water was measured to check against the previously measured injected water. All samples were submitted to the W. M. Ward Technical Services Laboratory on November 21, 1984 for chemical analyses.

3.0 GEOPHYSICAL PROGRAM

3.1 GEONICS EM-31 TERRAIN CONDUCTIVITY STUDY

The results of the Geonics EM-31 terrain conductivity survey can be seen in Figure 2. A plume-like conductivity anomaly was successfully mapped mostly within the units of the most recent meander scar of the Assiniboine River. Conductivity values are contoured in logarithmic limits where 50 milliSiemens/metre was selected as a representative background reading. The surficial geology of the landfill site and its environs is complex and the contoured plume-like anomaly is believed to represent the major concentrations of a ground water contaminant plume. This will be further discussed in Section 7.1.

3.2 GEONICS EM-16R VLF TERRAIN RESISTIVITY STUDY

The results of the Geonics EM-16R VLF resistivity survey can be seen in Figure 3. All values were converted to units of conductivity for ease in comparing to the EM-31 survey (Figure 2). The results of the deeper penetrating EM-16R survey were not contoured since the purpose of this survey was to augment the EM-31 survey.

Electrical conductivity patterns were similar to those observed in the EM-31 survey. The meander scar exhibited high conductivity compared to the surrounding soils. A lower EM-16R phase difference was also recorded at most places in the meander scar. At this site the lower phase readings are due to the soils having less of an electrically resistive soil overlying the clays found to depth.

3.3 GEOELECTRIC RESISTIVITY SOUNDINGS

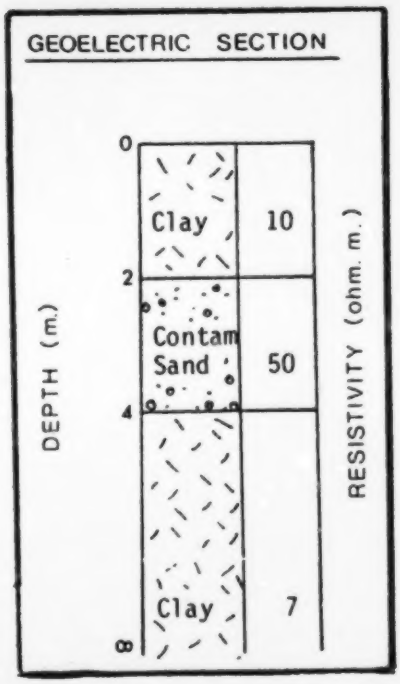
The purpose of the geoelectric soundings was to gain some additional knowledge of the subsurface geology prior to the drilling program. The locations of the four-electrode resistivity soundings can be seen on Figure 3 and the results are given in Appendix 1. Figure 4 outlines the geoelectric profile determined at each location using the Master Curve Method (Lazrag, 1972) and Inverse Computer Model Method (Davis, 1979). Soundings 1, 2, and 4 show a sand layer is present approximately from 2 to 4 m. Sounding No. 3 was performed in an area where earth material was being removed to cover the landfill. The results of this sounding show that sand is present to approximately 1.5 m where it is underlain by clay to an approximate depth of 23 m. A correlation of geophysical and geological results is discussed in Section 7.0.

4.0 GEOLOGY

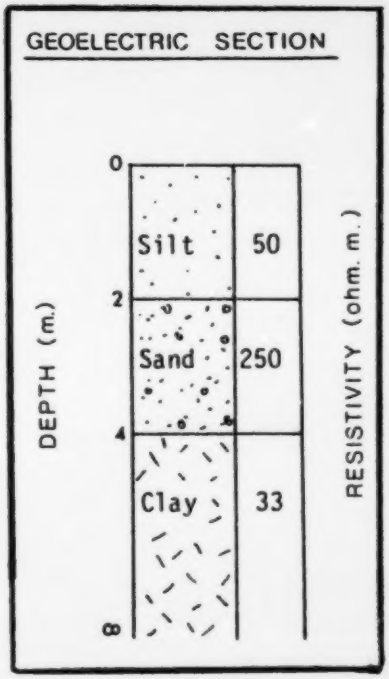
4.1 REGIONAL GEOLOGY

The regional geology of the Portage La Prairie area, as described by Water Resources Division, Manitoba (1965), consists of surficial deposits of silts and silty sands. These are believed to have been deposited by the last phase of glacial Lake Agassiz. These deposits are underlain by lacustrine clays to depths of about 30 m, which are in turn underlain by glacial till. The gravelly till unit is underlain by a gypsiferous dolomite bedrock (Amaranth Formation) of Jurassic Age. This formation is believed to occur at depths of about 36 m beneath the southern portion of Portage La Prairie.

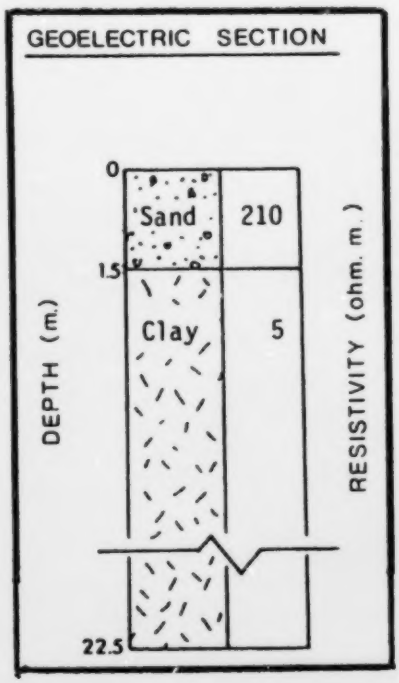
FIGURE 4: GEOELECTRIC CROSS-SECTIONS



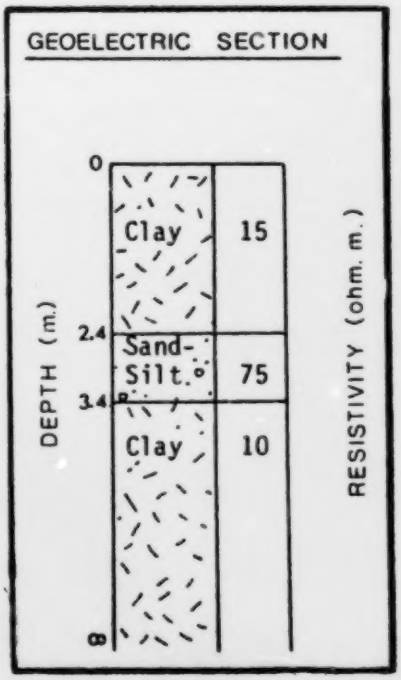
SOUNDING NO. 1



SOUNDING NO. 2



SOUNDING NO. 3



SOUNDING NO. 4

(See Figure 3 for locations)

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The surficial deposits of silt and silty sands in the vicinity of the landfill have been reworked by the erosive action of the Assiniboine River. In this respect, a large meander belt has been created with numerous meander scars and oxbow lakes. The meander scars have been infilled with fluvial deposits of clays, sands and silts.

4.2 SITE GEOLOGY

The surficial geology surrounding the Portage La Prairie landfill is complex owing to the numerous meander scars created by the Assiniboine River. The surficial geology of the landfill area is shown on Figure 5. The terrain was stereoscopically mapped using aerial photographs and confirmed during the site visits and drilling program. The remnant meander scars, most recent meander scar and alluvial silts all have characteristic geology. However, a 1 to 3 m thick sand layer appears to underlie the whole area at depths ranging from 1 to 5 m below the surface. Figure 6 shows the consistency of this sand layer in north-south and east-west cross-sections referenced to Figure 5.

The near-surface geology of the recent meander scars consists of a silty clay to clayey silt. This unit is underlain by the 1 to 3 m thick, fine to medium sand layer. This in turn is underlain by what is assumed to be a thick sequence of lacustrine clay. Detailed geological descriptions of the soils at each borehole are given in Appendix 2.

The geology of the remnant meander scar areas consists of a 1 to 4 m thick sequence of silt which overlies the sand layer. The sand layer is again assumed to be underlain

by lacustrine clay. The presence of a thick clay sequence in indicated based on interpretation of the geophysical results. No test wells were installed in the refuse or the alluvial silt area.

5.0 HYDROGEOLOGY

Two aquifers are present in the area. One is a shallow sand aquifer 1 to 3 m thick as shown on Figure 6. This aquifer supplies water to some local wells along Hwy. 240. A second, deeper bedrock aquifer of regional significance occurs at a depth of about 36 m. This deeper aquifer has not been considered in this study as it is confined by a thick, consistent low permeability lacustrine clay (Water Resources Division, Manitoba, 1965).

Of major importance from a contaminant migration point of view is the shallow sand aquifer. Figure 7 outlines the inferred directions of ground water flow in the shallow aquifer near the landfill site. Contoured data are for one set of water level measurements recorded on November 20, 1984 (Appendix 3). Monitor details are also listed in Appendix 3. Ground water flows in a south-southwesterly direction away from the landfill with localized flow in the meander scar following a southerly trend.

Although no monitors were constructed to the west of Highway 240, it is likely that a component of flow in the shallow aquifer will flow towards the west. This component of flow will be controlled to some extent by the elevation of the leachate mound in the landfill and discharge to

the Assiniboine River to the west. Insufficient hydraulic data are available, in and north of the landfill, to confirm the presence of a mound and localized radial flow close to the landfill.

Recharge to the shallow aquifer is from direct infiltration of rainfall or snowmelt. The shallow aquifer discharges to the Assiniboine River.

Ground water flow rates are likely in the order of 130 m/a (Appendix 4) in the shallow aquifer. The underlying clay formation is likely an aquitard which prevents flow to depth. However, there are no installations in this formation to confirm hydraulic gradients.

Data from Borehole 9 (north of the landfill) was not contoured but it has the highest water level of the 9 test wells installed. A large ground water mound likely exists in the 10 m to 15 m above grade landfill. This assumed mound will have a localized affect on the ground water flow regime near the vicinity of the landfill.

6.0 GEOCHEMISTRY

A historical summary of water chemistry analyses from domestic wells in the vicinity of the Portage La Prairie landfill was examined for this study. Data from September, 1981 to August, 1984 were evaluated along with one set of data from the test wells installed by Gartner Lee Associates Limited. The results of the chemical analysis on the ground water from the test wells is appended in Appendix 5. The following sections are based on specific leachate parameters identified and their significance in relation to the local hydrogeology.

6.1 ARSENIC

Figure 8 is a map of arsenic concentrations in the ground water sampled from domestic and test wells in August and November, 1984. The ground water from several wells south and south-southwest of the landfill have arsenic concentrations greater than the Canadian Drinking Water Standard (0.05 mg/L). There is also a high incidence of ground water that has arsenic concentrations greater than background values. These wells are located in the ground water flow path, down gradient from the landfill. Background arsenic concentrations in the shallow aquifer are likely 0.001 mg/L.

Arsenic is a relatively mobile compound in ground water. Freeze and Cherry (1979) state that dominant dissolved species of arsenic are either uncharged or negatively charged. This suggests that adsorption and ion exchange will cause little retardation as these species are transported along ground water flow paths.

Tests well 9, north of the landfill, also shows a high level of arsenic in the ground water. This level is just below the Drinking Water Standard. The northerly migration of arsenic in the ground water is likely related to radial flow from the ground water mound in the landfill.

6.2 CHLORIDE

Figure 9 is a map of chloride concentrations in the ground water sampled from domestic and test wells in May and November, 1984. The ground water from several wells south and south-southwest of the landfill have chloride concentrations greater than background concentrations. A conservative estimate of 50 mg/L was chosen to represent

a background concentration after evaluating the regional geochemistry. The wells of concern are located in the ground water flow path, downgradient from the landfill. Chloride is a good indicator of contaminant migration from a landfill since its mobility is not influenced by geochemical processes such as adsorption, precipitation, oxidation or reduction (Cherry et al, 1982).

Several wells down gradient from the landfill have water softeners attached to their pumping facilities. The potential exists for these domestic wells to be affected by chloride induced from the water softeners. This could occur when softener tanks are backwashed to septic leaching beds. As a result these wells are highlighted in Figure 9. Due to infrequent use of road salt on Highway 240, it is felt that the high chloride concentrations are likely caused by landfill leachate or water softener backwash.

6.3 IRON

Figure 10 is a map of iron concentrations in the ground water sampled from domestic and test wells in May and November, 1984. The ground water from several wells south and south-southwest of the landfill have iron concentrations several times higher than the Canadian Drinking Water Standard (0.3 mg/L). The wells of concern are located in the ground water flow path, down gradient from the landfill. Iron is a reliable parameter for indicating contamination of ground water by landfill leachate (Clark and Piskin, 1977). Background levels of iron in the shallow aquifer are likely less than 0.1 mg/L.

Several wells downgradient from the landfill have regular

filters or iron filters attached to their pumping facilities. These wells have been highlighted on Figure 10. It should also be noted that some of the iron found in the domestic wells may be attributed to steel well points. The test wells installed by Gartner Lee Associates Limited will not affect the iron concentrations in the ground water samples since they are constructed of PVC.

Test well 9, north of the landfill, also shows a high level of iron in the ground water. The northerly migration of iron in the ground water is likely related to radial flow from the ground water mound within the landfill.

6.4 BICARBONATE

Figure 11 is a map of bicarbonate concentrations in the ground water sampled from domestic and test wells in May and November, 1984. The ground water from twelve wells south of the landfill have bicarbonate concentrations greater than background concentrations. A conservative estimate of 650 mg/L was chosen to represent a background concentration after evaluating the regional geochemistry. Most of the wells of concern are located immediately downgradient from the landfill. Clark and Piskin (1977) state that bicarbonate is a landfill leachate characteristic parameter.

7.0 DISCUSSION

7.1 LIMITATIONS

Geochemical results from all domestic wells in the vicinity of the landfill site were incorporated into the ground water contamination analysis and interpretation. The main limiting factor in this study was that there is no geological or hydrogeological control for these wells. That is, there is no information on these well's depth, screened interval or a geological record of the subsurface. Also in analysing the geochemical data it was noticed that water softeners or filters are present on many of the domestic wells. Subsequently, any domestic well with a filter or softening unit was not used in interpreting the ground water chemistry downgradient of the landfill.

Another limiting factor was that no test wells were installed in the landfill to determine the amount of ground water mounding. If a mound exists it will hydraulically control the movement of ground water in the vicinity of the landfill. The mound in the landfill was not investigated since the purpose of this study was to define the extent of ground water contamination.

The natural conducting properties of the native soils were also a limiting factor. Electrical ground water geophysical techniques work best in resistive or sandy geological environments. The soils surrounding the landfill site are clayey and silty making ground water contamination detection difficult.

7.2 GEOPHYSICAL PROGRAM

The surficial geology of the Portage La Prairie landfill site and environs is complex, however, the shallow penetrating electrical conductivity survey (EM-31) mapped the major concentrations of a contaminant plume in the meander scar south of the landfill. There are four distinct surficial geological regions within the landfill area as discussed in Section 4.2. These four surficial geological regions all have their own electrical conductivity signature depending on the depositional environment and the amount of clay present within the soil matrix.

The electrical conductivity anomaly mapped with the EM-31 is in an area where fluvial clays were deposited to depths ranging from 1.0 to 4.5 m. Clay is an excellent conductor of electricity making the mapping of ground water conductivity contrasts difficult. However, a definite plume-like anomaly was mapped where terrain conductivities are highest near the landfill. The conductivity values in the meander scar decrease as a function of distance away from the landfill whereas the thickness of the clay layer increases as shown in the cross-section of Figure 6. This conductivity anomaly is therefore believed to be the most concentrated area of a ground water contaminant plume.

7.3 HYDROGEOLOGY AND GEOCHEMISTRY PROGRAM

Ground water flows in a south-southwesterly direction away from the landfill at rates on the order of 130 m/a. Therefore, the potential exists for contaminated ground waters to have migrated to the Assiniboine River some 1200 m to the south, during the 50 year history of the landfill. Localized ground water flow appears to be channelled in to the low lying meander scar of the Assiniboine River which also is oriented in a southerly direction.

The ground water contaminant plume is likely migrating slower than the velocity of the ground water owing to the attenuating capability of the sandy soils. Pumping of the ground water from this shallow aquifer may cause the contaminant plume to affect other domestic wells down gradient of the landfill in the future.

It appears that only some of the wells in the shallow sand aquifer have been impacted with landfill leachate. Domestic wells located in the deeper bedrock aquifer have not been considered in this study as they are confined by a thick, low permeability lacustrine clay (Water Resources Division, Manitoba, 1965).

A ground water mound has likely formed in the landfill. This mound will have radial flow associated with it which at least locally will migrate in a northerly direction, against the regional flow gradient. Further definition of the mound will be needed to evaluate the movement of ground water north of the landfill.

A total of four leachate indicator chemical parameters were used to evaluate contaminant migration from the

landfill. All four parameters, arsenic, chloride, iron and bicarbonate were found in the ground water from most of the domestic and test wells located south of the landfill. Other chemical parameters such as alkalinity and sulphate showed a similar trend. The ground water from some domestic and test wells immediately south of the landfill exceed the Canadian Drinking Water Standard limits for arsenic, chloride and iron.

A reduction in landfill leachate production could be achieved by covering the landfill with a low permeability clay cap. This would lead to a long-term reduction in contaminant concentrations but is not an instant solution.

The above discussion is based on two to four sets of water chemistry data from domestic wells and one set of data from test wells. Also, only one set of water level measurements have been recorded. Chemistry and water level data will fluctuate with time, therefore, a semi-annual monitoring program is recommended.

Respectfully submitted,

GARTNER LEE ASSOCIATES LIMITED

David D. Slaine

David D. Slaine, M.Sc.,
Hydrogeologist.

8.0 REFERENCES

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1980: Electromagnetic Terrain Conductivity Measurements at Low Induction Numbers. Geonics Ltd. Technical Note TN-6, Mississauga, Ontario, 15 pp.

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1965: Geological and Ground Water Investigation for the Portage Division. Planning Division. 65 pp.

9.0 GLOSSARY OF TERMS

BISON EARTH RESISTIVITY METER, MODEL 2350

A geophysical instrument manufactured by Bison Inc. where a total of four electrodes are pushed into the ground to a depth of a few inches, at locations a few metres apart. Electrical current from a battery is forced to flow into the ground through two of these electrodes. The resulting voltage drop produced by this current in the earth is measured across the other two electrodes. The voltage drop will be affected differently by different subsurface conditions. Interpretation of electrical resistivity readings gives an understanding of the subsurface conditions. The 2350 model has an exploration depth of approximately 30 metres.

CONTAMINANT PLUME

A zone of diluted landfill leachate within a ground water flow system usually migrating slower than the ground water velocity.

ELECTRICAL CONDUCTIVITY

The ability of a geologic formation to pass an electric current. Electrical conductivity is the inverse of electrical resisitivity.

ELECTRICAL RESISITIVITY

The electrical resistance of a geological formation to an electric current. In a saturated rock or soil, the resistivity is largely dependent on the density and porosity of the material and the salinity of the saturating fluid. Electrical resistivity is the inverse of electrical conductivity.

GEOCHEMISTRY

The science involving the chemistry of underground water.

GEONICS EM-16R VLF

A geophysical instrument manufactured by Geonics Ltd. Horizontally polarized magnetic fields are transmitted at VLF (Very Low Frequencies) from a submarine navigation antenna. The amplitude of the ratio of VLF electric and magnetic fields recorded on the ground surface is a measure of the average earth resistivity to a depth of about 25 to 40 metres. The phase angle between electric and magnetic fields provides information on the conductivity structure of the zone sampled. The unit is run by one person and measures amplitude in ohm metres and the phase angle in degrees.

GEONICS EM-31

A geophysical instrument manufactured by Geonics Ltd. Transmitter and receiver coils on this unit are separated by a 3 metre long frame which can be carried by one person. No ground contact is required. The receiver records the quadrature component of the magnetic field due to currents induced by the transmitter field. This quadrature component is linearly related to the apparent conductivity, which is a weighted average of the earth conductivities to a depth of about 4 to 5 metres.

GEOELECTRIC

The electrical resistivity (conductivity), signature of a specific geologic formation.

GROUND WATER MOUND

An increase in the height of the ground water table where the infiltration of water exceeds the rate at which water can flow away through the ground.

HYDROGEOLOGY

The study of water moving through geologic materials.

LEACHATE

The liquid which escapes from a landfill as the result of water percolating through the refuse and picking up certain soluble waste fractions en route.

MEANDER BELT

The zone along a river valley floor that encloses a meandering river.

MEANDER SCAR

A turn or sharp bend in a river's course that has been infilled with sediment.

A P P E N D I X 1

FOUR-ELECTRODE RESISTIVITY SOUNDING DATA

Four Electrode Resistivity Sounding No. 1

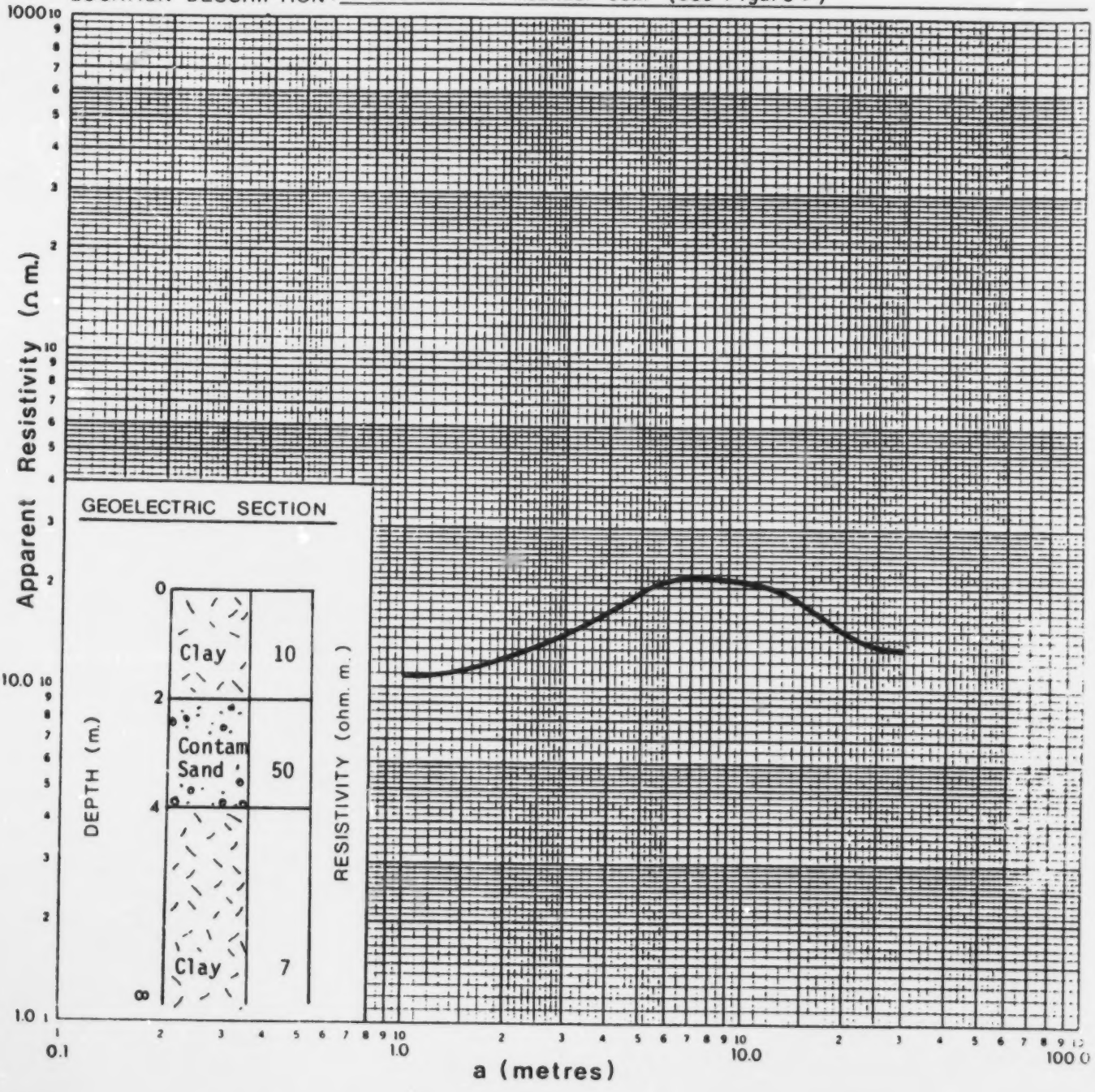
STUDY: Portage La Prairie Landfill Hydrogeological Study

PROJECT NO.: 84-96 DATE: Oct.10/84 OPERATOR: D.D. Slaine

ARRAY TYPE: Wenner

EQUIPMENT: Bison 2350 Resistivity Meter

LOCATION DESCRIPTION: West arm of meander scar (See Figure 3)



Four Electrode Resistivity Sounding No. 2

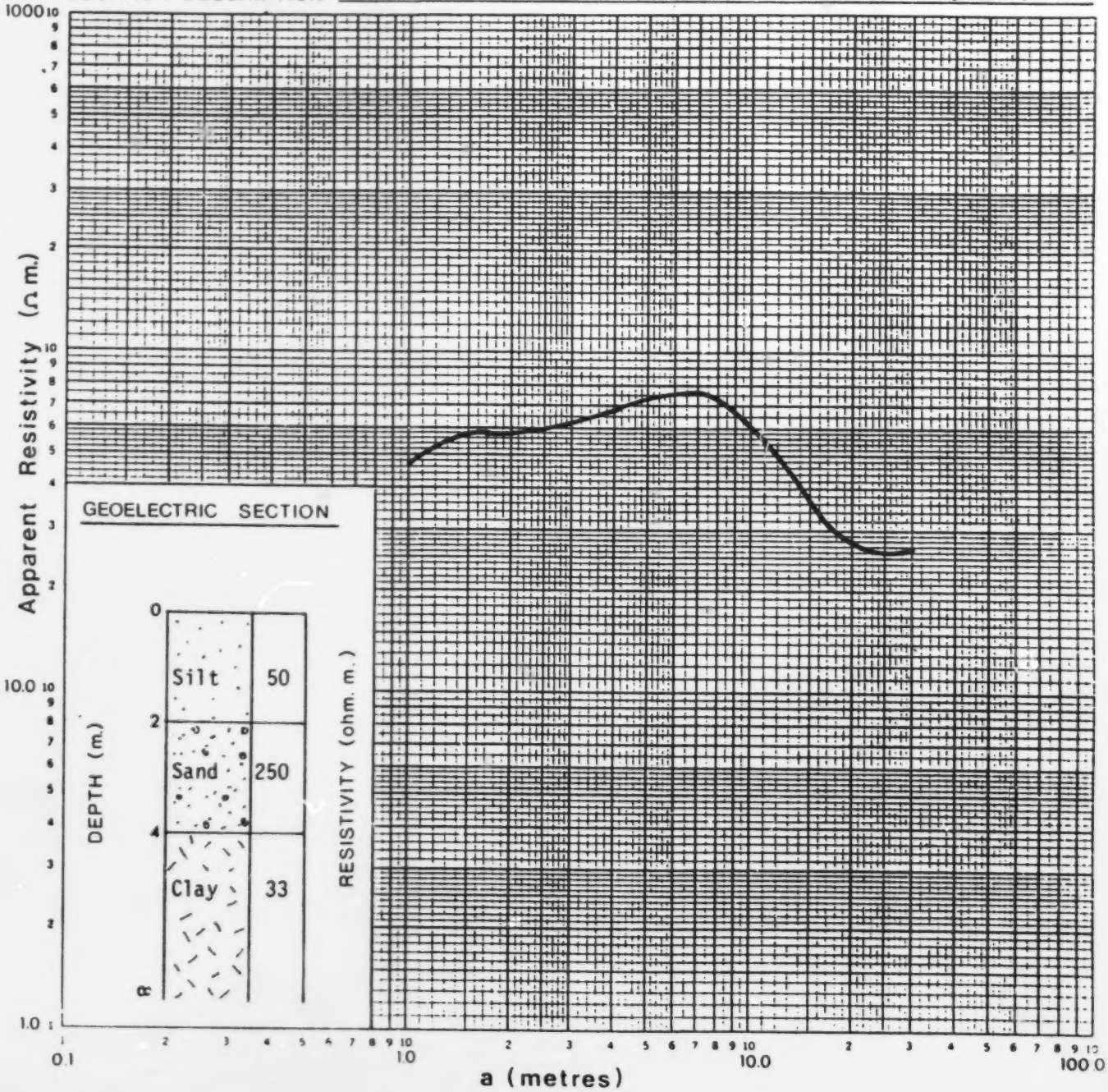
STUDY: Portage La Prairie Landfill Hydrogeological Study

PROJECT NO.: 84-96 DATE: Oct.10/84 OPERATOR: D.D. Slaine

ARRAY TYPE: Wenner

EQUIPMENT: Bison 2350 Resistivity Meter

LOCATION DESCRIPTION: Path perpendicular to both meander scars (see Figure 3)



Four Electrode Resistivity Sounding No. 3

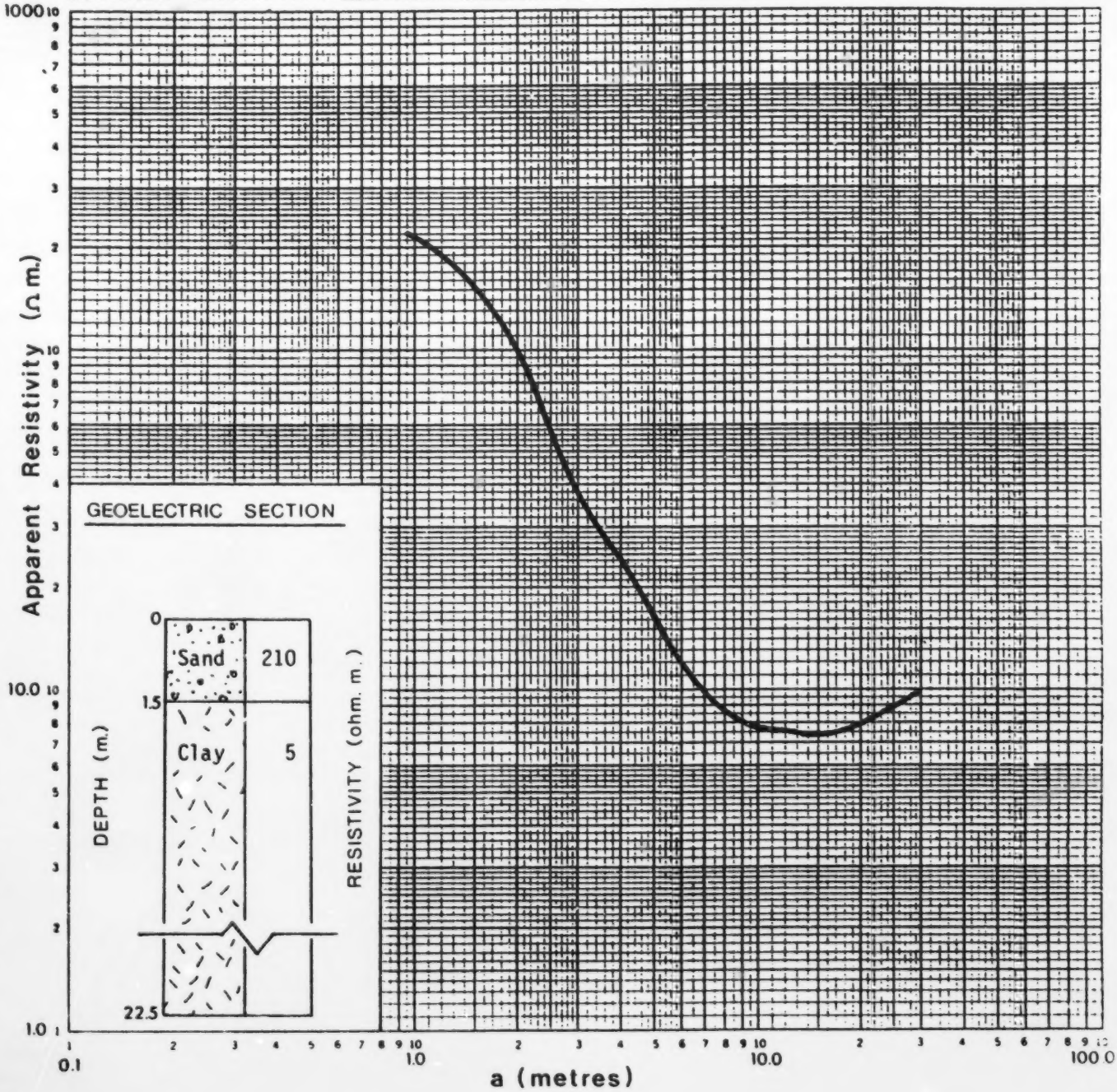
STUDY: Portage La Prairie Landfill Hydrogeological Study

PROJECT NO.: 84-96 DATE: Oct. 10/84 OPERATOR: D.D. Slaine

ARRAY TYPE: Wenner

EQUIPMENT: Bison 2350 Resistivity Meter

LOCATION DESCRIPTION: Sand pit southeast of landfill (see Figure 3)



Four Electrode Resistivity Sounding No. 4

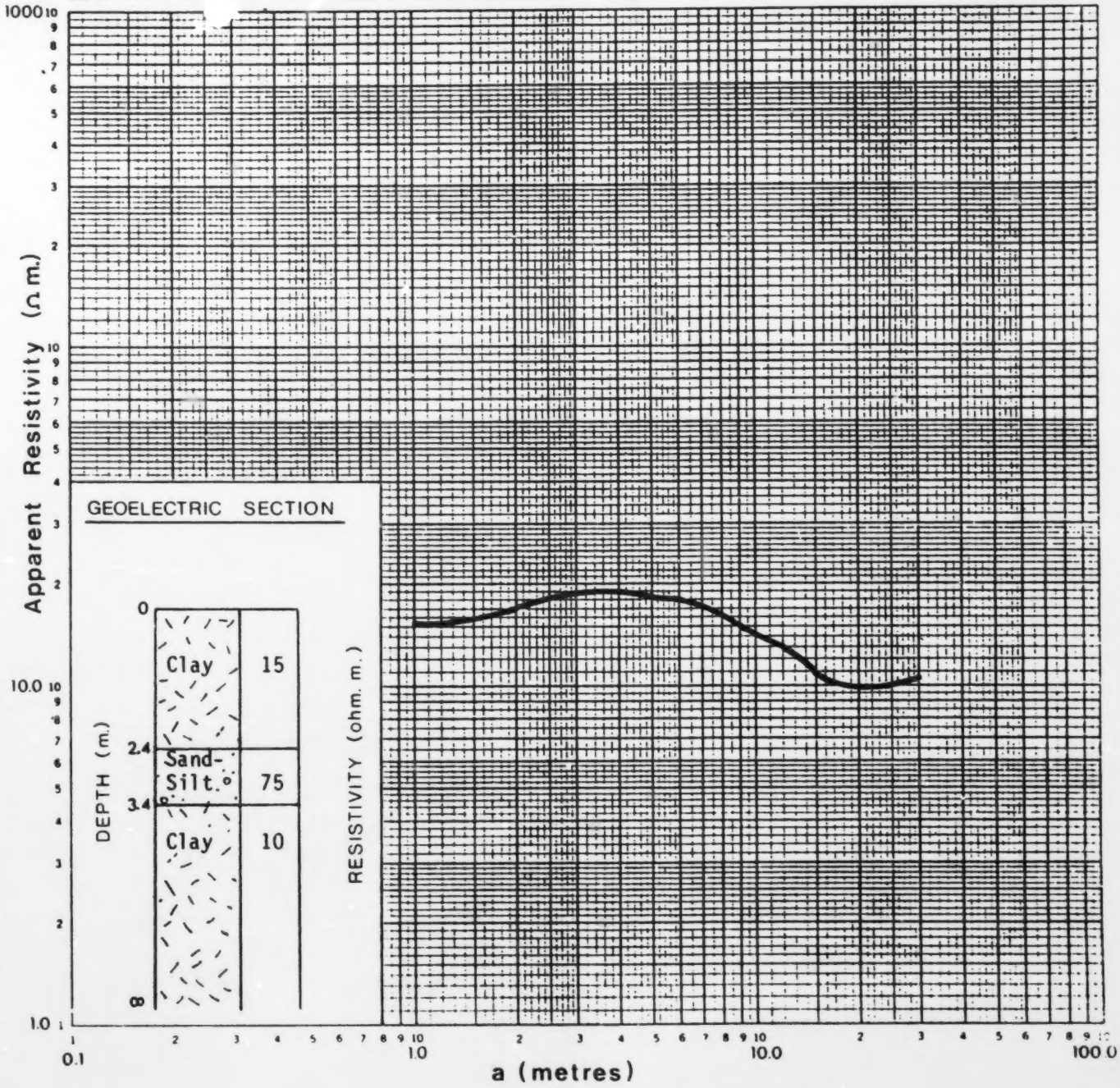
STUDY: Portage La Prairie Landfill Hydrogeological Study

PROJECT NO: 84-96 DATE: Oct. 10/84 OPERATOR: D.D. Slaine

ARRAY TYPE: Wenner

EQUIPMENT: Bison 2350 Resistivity Meter

LOCATION DESCRIPTION: East of landfill near cemetery (see Figure 3)



APPENDIX 2

BOREHOLE LOGS

LIST OF ABBREVIATIONS

PENETRATION RESISTANCE:

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split-spoon sampler 300 mm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 750 mm.

Dynamic Penetration Resistance - The number of blows required to advance a 50 mm, 60 degree cone, fitted to the end of drill rods, 300 mm into the subsoil, the driving energy being 475 J per blow.

DESCRIPTION OF SOIL:

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows/300 mm	Denseness	'N' Blows/300 mm
Very Soft	0 - 2	Very Loose	0 - 4
Soft	2 - 4	Loose	4 - 10
Firm	4 - 8	Compact	10 - 30
Stiff	8 - 15	Dense	30 - 50
Very Stiff	15 - 30	Very Dense	>50
Hard	>30		

W.T.P.L.	-	Wetter than Plastic Limit
D.T.P.L.	-	Drier than Plastic Limit
A.P.L.	-	About Plastic Limit

TYPE OF SAMPLE:

SS	-	Split Spoon
AS	-	Auger Sample
ST	-	Shelby Tube Sample

SYMBOLS:

▲	-	Water Table Monitor (Standpipe Tip)
●	-	Piezometer Tip
W.L.	-	Water Level
P.H.	-	Piezometric Head

BOREHOLE NO. 1

PROJECT NAME: Portage La Prairie Landfill Hydrogeological Study
CLIENT: Department of Supply and Services Canada
BOREHOLE TYPE: Backhoe and Water Jet
GROUND ELEVATION: Relative 29.26 m
DATE: Oct. 21/84
GEOLOGIST: DDS
PROJECT NO.: 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0									
0.1	Clayey TOPSOIL, Dark Brown								
	SILTY CLAY TO CLAYEY SILT Brown grading to grey with black organic debris and shells, A.P.L.			1			63		
0.70									
	Medium grained SAND Grey, Silty, Odourous			2			29		
3.54									
	Borehole terminated at ±3.54 m assumed in clay								
5.0									

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BOREHOLE NO. 2

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada DATE Oct. 22, 1984

BOREHOLE TYPE Backhoe and Water Jet GEOLOGIST DDS

GROUND ELEVATION Relative 30.98 m PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % Wp — Wl / COMMENTS
0	Clayey Silt TOPSOIL Dark brown, moist, rootlets								
0.50	Sandy SILT Interlayers of 1 to 2 cm seams of light brown silt and fine grained sand. D.T.P.L.			1			34		
				2			32		
2.70	Medium grained SAND Light brown grading to grey, saturated at ±3.4 m			3			11		
				4			21		
5.0									

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BOREHOLE NO. 2

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada DATE Oct. 22, 1984

BOREHOLE TYPE Backhoe and Water Jet GEOLOGIST DDS

GROUND ELEVATION Relative 30.98 m PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS Wp — Wl
5.0	Medium grained SAND (continued)								
6.30	Borehole terminated at ±6.30 m assumed in clay								

BOREHOLE NO. 3

PROJECT NAME: Portage La Prairie Landfill Hydrogeological Study
CLIENT: Department of Supply and Services Canada — DATE: Oct. 22, 1984
BOREHOLE TYPE: Backhoe and Water Jet — GEOLOGIST: DDS
GROUND ELEVATION: Relative 29.04 m — PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0	TOPSOIL Brownish-black organic matter, moist								
0.30				1			59		
	Silty, CLAY to clayey SILT Brown grading to grey with black organic debris and shells. W.T.P.L								
2.05				2			50		
	Medium grained SAND Grey, saturated			3			20		
4.16									
	Borehole terminated at ± 4.16 m assumed in clay								
5.0									

Wp ——— Wl

Gartner Lee Associates Limited

BOREHOLE NO. 4

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada DATE Oct. 22/84

BOREHOLE TYPE Backhoe and Water Jet GEOLOGIST DDS

GROUND ELEVATION Relative 31.92 m PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0	TOPSOIL								
0.30	Dark brown, silty, moist								
	Sandy SILT Light brown, some layers of light brown fine grained sand, 1 to 2 cm thick. D.T.P.L.			1			12		
3.60	Silty Fine SAND Brown grading to grey with some thin layers (1 to 2 cm) of grey silty clay. Saturated at ±3.90 m			2			30		
5.0									

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BOREHOLE NO. 4

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada DATE Oct. 22/84

BOREHOLE TYPE Backhoe and Water Jet GEOLOGIST DDS

GROUND ELEVATION Relative 31.92 m PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
5.0	Silty Fine SAND (continued)								
5.64	Borehole terminated at ±5.64 m assumed in clay								

BOREHOLE NO. 5

PROJECT NAME: Portage La Prairie Landfill Hydrogeological Study

CLIENT: Department of Supply and Services Canada — DATE: Oct. 22/84

BOREHOLE TYPE: Backhoe and Water Jet — GEOLOGIST: DDS

GROUND ELEVATION: Relative 29.28 m — PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0	TOPSOIL Dark brown, organic, moist								
0.35	Silty CLAY to Clayey SILT Brown grading to grey with black organic debris and shells. W.T.P.L.			1			42		
				2			45		
2.45	Medium grained SAND Grey, saturated			3			24		
4.26	Borehole terminated at ±4.26 m assumed in clay								
5.0									

Wp ——— Wl

Gartner Lee Associates Limited

BOREHOLE NO. 6

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada **DATE** Oct. 22/84

BOREHOLE TYPE Backhoe and Water Jet **GEOLOGIST** DDS

GROUND ELEVATION Relative 29.40 m **PROJECT NO.** 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0	TOPSOIL								
0.35	Dark brown, clayey								
	Clayey SILT								
	Brown, A.P.L.			1			29		
0.90									
	Medium grained SAND			2			21		
	Red brown, saturated at ±1.30 m								
4.0									
	Borehole terminated at ±4.0 m assumed in clay								
5.0									

Wp —— Wl

Gartner Lee Associates Limited

BOREHOLE NO. 7

PROJECT NAME: Portage La Prairie Landfill Hydrogeological Study
CLIENT: Department of Supply and Services of Canada
DATE: Oct. 23, 1984
BOREHOLE TYPE: Backhoe and Water Jet
GEOLOGIST: DDS
GROUND ELEVATION: Relative 29.66 m
PROJECT NO.: 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0	TOPSOIL Dark brown, silty								Wp — Wl
				1			44		
0.50	Medium grained SAND Light brown to red brown, moist			2			65		
1.85									
1.95	Clayey SILT-Grey, W.T.P.L.			3			37		
				4			19		
	Medium grained SAND Grey, Saturated								
4.42									
5.0	Borehole terimated at ±4.42 m assumed in clay								

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BOREHOLE NO. 8

PROJECT NAME: Portage La Prairie Landfill Hydrogeological Study

CLIENT: Department of Supply and Services Canada — DATE: Oct. 23, 1984

BOREHOLE TYPE: Backhoe and Water Jet — GEOLOGIST: DDS

GROUND ELEVATION: Relative 29.29 m — PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0	TOPSOIL								
0.30	Dark brown, Clayey, A.P.L.								
	Clayey SILT to Silty CLAY Brown with 2 to 10 cm seams of light brown silt, W.T.P.L.			1			46		
2.10									
	Clayey SILT to Silty CLAY Grey, W.T.P.L.			2			38		
4.50									
	Medium grained SAND Grey, silty, saturated			3			25		
5.0									

Gartner Lee Associates Limited

BOREHOLE NO. 8

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada DATE Oct. 23, 1984

BOREHOLE TYPE Backhoe and Water Jet GEOLOGIST DDS

GROUND ELEVATION Relative 29.29 m PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % Wp — Wl / COMMENTS
5.0	Medium grained SAND (continued)								
5.48	Borehole terminated at ±5.48 m assumed in clay								

BOREHOLE NO. 9

PROJECT NAME Portage La Prairie Landfill Hydrogeological Study

CLIENT Department of Supply and Services Canada DATE Oct. 23, 1984

BOREHOLE TYPE Backhoe and Water Jet GEOLOGIST DDS

GROUND ELEVATION Relative 30.49 m PROJECT NO. 84-96

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0									
0.10	TOPSOIL- Dark brown, Silty								
	SILT Light brown, D.T.P.L.			1			26		
1.60									
	Clayey SILT to Silty CLAY Grey, A.P.L.			2			46		
2.70									
	Medium grained SAND Grey, saturated			3			20		
4.42									
	Borehole terminated at ±4.42 m assumed in clay								
5.0									

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APPENDIX 3

MONITOR DETAILS AND WATER LEVEL MEASUREMENTS

PROJECT NO. 84-96

TABLE 1 SHEET 1

MONITOR DETAILS

BOREHOLE NO.	MONITOR NO.	DIAMETER (mm)	TOP OF PIPE ELEV. * (m)	STICKUP (m)	GROUND ELEV. * (m)	TYPE	SCREENED INTERVAL		GRAVEL PACK	SEAL
							DEPTH FROM GRADE (m)	*ELEVATION (m)	DEPTH FROM GRADE (m)	DEPTH FROM GRADE (m)
1	I	38	30.17	0.91	29.26	▲	0.64 - 3.54	28.62 - 25.72	natural sand pack for all monitors	Back-filled from surface with native clay and/or silt.
2	I	38	32.02	1.04	30.98	▲	3.38 - 6.30	27.60 - 24.68		
3	I	38	29.96	0.92	29.04	▲	1.73 - 4.16	27.31 - 24.88		
4	I	38	33.09	1.17	31.92	▲	2.90 - 5.64	29.02 - 26.28		
5	I	38	30.31	1.03	29.28	▲	2.31 - 4.26	26.97 - 25.02		
6	I	38	30.35	0.95	29.40	▲	1.27 - 4.00	28.13 - 25.40		
7	I	38	30.65	0.99	29.66	▲	1.68 - 4.42	27.98 - 25.24		
8	I	38	30.21	0.92	29.29	▲	3.97 - 5.48	25.32 - 23.81		
9	I	38	31.47	0.98	30.49	▲	1.68 - 4.42	28.81 - 26.07		

* Relative elevation (m)

● = Piezometer ▲ = Standpipe

PROJECT: 84-96 DEPT. OF SUPPLY & SERVICES SHEET 01 of 01

GROUND WATER LEVEL RESULTS

BOREHOLE NUMBER	MONITOR No.	TYPE	GROUND SURFACE ELEVATION (m REF)	REFERENCE POINT(RP) ELEVATION (m REF)	DATE 20 NOV 84 DEPTH (m BRP)	ELEV'N (m REF)
1	I	S	29.26	30.17	2.05	28.12
2	I	S	30.98	32.02	4.46	27.56
3	I	S	29.04	29.96	2.46	27.50
4	I	S	31.92	33.09	5.28	27.81
5	I	S	29.28	30.31	2.85	27.46
6	I	S	29.40	30.35	2.48	27.87
7	I	S	29.66	30.65	2.78	27.87
8	I	S	29.29	30.21	3.03	27.18
9	I	S	30.49	31.47	2.76	28.71

NOTES: P-Piezometer S-Standpipe

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APPENDIX 4

GROUND WATER VELOCITY CALCULATIONS

Ground water velocity calculations are based on the Darcy flux. The equation, listed below, incorporates the hydraulic conductivity (permeability) of the soil and the change in the ground water gradient. The values for hydraulic conductivity were taken from a Water Resources Division - Manitoba (1965) publication for the Portage region. The hydraulic conductivity of 5.6×10^{-4} m/s is the average of pump test data and grain size determination data listed in the report. This is a typical value for a medium grained sand. The hydraulic gradient is a measurement of the change in hydraulic head over a lateral change is distance. The porosity value used in the average linear ground water calculation is also typical for a medium grained sand.

Darcy Flux Calculation

$$V = -K\frac{dh}{dl}$$

where v = Darcy flux (m/s)

$-K$ = hydraulic conductivity (m/s)

dh = change in hydraulic head (m)

dl = change in distance between observation points (m)

Average Linear Ground Water Velocity Calculation

$$\overline{v} = \frac{v}{n}$$

$\overline{v}$ = average linear ground water velocity (m/s)

v = Darcy flux (m/s)

n = porosity (dimensionless)

Borehole 1 to Borehole 3

Darcy Flux (v)

$v = -K\frac{dh}{dl}$

$v = 9.6 \times 10^{-7}$ m/s

$= 30$ m/a

$K = 5.6 \times 10^{-4}$ m/s

$dh = 0.62$ m

$dl = 360$ m

Average Linear Ground Water Velocity ($\bar{v}$)

$\bar{v} = v/n$

$\bar{v} = 150$ m/a

$v = 0.54$ m/a

$n = 0.20$

Borehole 1 to Borehole 8

Darcy Flux (v)

$v = -K\frac{dh}{dl}$

$= 7.6 \times 10^{-7}$ m/s

$= 24$ m/a

$K = 5.6 \times 10^{-4}$ m/s

$dh = 0.94$ m

$dl = 690$ m

Average Linear Ground Water Velocity ($\bar{v}$)

$\bar{v} = v/n$

$\bar{v} = 120$ m/a

$v = 0.43$ m/a

$n = 0.20$

APPENDIX 5

GROUND WATER CHEMISTRY ANALYSES

FROM TEST WELLS

PROJECT 84-96

TABLE ___ SHEET 1

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #1 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	2200										
pH	7.20										
ALKALINITY ($CaCO_3$)	880										
ALKALINITY (HCO_3)	1070										
HARDNESS ($CaCO_3$)	838										
CHLORIDES (Cl)	170										
SULPHATE (SO_4)	215										
PHOSPHORUS (TOTAL)	1.0										
TOTAL KJELDAHL	4.9										
AMMONIA (NH_3-N)	3.6										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1750										
RESIDUE FILTERED	1490										
RESIDUE NON FILTERED	270										
COD	81										
TOC	88										
TURBIDITY (NTU)	100										
POTASSIUM (K)	15.5										
MAGNESIUM (Mg)	81.9										
CALCIUM (Ca)	201										

NOTE: concentrations in p.p.m. unless otherwise noted.

Gartner Lee Associates Limited

PROJECT 84-96 TABLE___ SHEET 2

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #1 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	193										
IRON (Fe)	21.7										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.075										
CADMIUM (Cd)	<.001										
COPPER (Cu)	<.01										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.02										
ZINC (Zn)	<.01										
CHROMIUM (Cr)	0.011										
MANGANESE (Mn)	1.77										

NOTE: concentrations in p.p.m. unless otherwise noted.

Gartner Lee Associates Limited

PROJECT 84-96

TABLE ___ SHEET 3

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #2 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	2420										
pH	7.20										
ALKALINITY ($CaCO_3$)	872										
ALKALINITY (HCO_3)	1060										
HARDNESS ($CaCO_3$)	872										
CHLORIDES (Cl)	230										
SULPHATE (SO_4)	255										
PHOSPHORUS (TOTAL)	1.3										
TOTAL KJELDAHL	6.1										
AMMONIA (NH_3-N)	4.5										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1850										
RESIDUE FILTERED	1630										
RESIDUE NON FILTERED	230										
COD	82										
TOC	113										
TURBIDITY (NTU)	150										
POTASSIUM (K)	-										
MAGNESIUM (Mg)	91.9										
CALCIUM (Ca)	198										

NOTE: concentrations in p.p.m. unless otherwise noted.

Gartner Lee Associates Limited

PROJECT 84-96

TABLE ___ SHEET 4

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #2 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	181										
IRON (Fe)	32.4										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	.143										
CADMIUM (Cd)	<.001										
COPPER (Cu)	<.01										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.009										
ZINC (Zn)	<.01										
CHROMIUM (Cr)	<.005										
MANGANESE (Mn)	1.57										

NOTE: concentrations in p.p.m. unless otherwise noted.

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PROJECT 84-96 TABLE ___ SHEET 5

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #3 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	1020										
pH	7.40										
ALKALINITY ($CaCO_3$)	404										
ALKALINITY (HCO_3)	493										
HARDNESS ($CaCO_3$)	519										
CHLORIDES (Cl)	19										
SULPHATE (SO_4)	150										
PHOSPHORUS (TOTAL)	0.24										
TOTAL KJELDAHL	0.7										
AMMONIA (NH_3-N)	0.41										
TOTAL NITRITE-NITRATE	0.01										
RESIDUE TOTAL	760										
RESIDUE FILTERED	680										
RESIDUE NON FILTERED	77										
COD	16										
TOC	71.5										
TURBIDITY (NTU)	100										
POTASSIUM (K)	5.25										
MAGNESIUM (Mg)	42.5										
CALCIUM (Ca)	138										

NOTE: concentrations in p.p.m. unless otherwise noted.

PROJECT 84-96 TABLE___ SHEET 6

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #3 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 198										
SODIUM (Na)	33.7										
IRON (Fe)	16.5										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.049										
CADMIUM (Cd)	<.001										
COPPER (Cu)	.03										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.006										
ZINC (Zn)	0.02										
CHROMIUM (Cr)	0.011										
MANGANESE (Mn)	1.66										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE___ SHEET 7

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well # 4 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	821										
pH	7.40										
ALKALINITY ($CaCO_3$)	352										
ALKALINITY (HCO_3)	429										
HARDNESS ($CaCO_3$)	398										
CHLORIDES (Cl)	15										
SULPHATE (SO_4)	100										
PHOSPHORUS (TOTAL)	0.08										
TOTAL KJELDAHL	0.40										
AMMONIA (NH_3-N)	0.24										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	560										
RESIDUE FILTERED	530										
RESIDUE NON FILTERED	37										
COD	10										
TOC	21										
TURBIDITY (NTU)	25										
POTASSIUM (K)	11.5										
MAGNESIUM (Mg)	30.6										
CALCIUM (Ca)	109										

NOTE: concentrations in p.p.m. unless otherwise noted.

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PROJECT 84-96 TABLE___ SHEET 8

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #4 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	17.4										
IRON (Fe)	4.88										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.018										
CADMIUM (Cd)	<.001										
COPPER (Cu)	<.01										
LEAD (Pb)	.007										
NICKEL (Ni)	.006										
ZINC (Zn)	<.01										
CHROMIUM (Cr)	<.005										
MANGANESE (Mn)	1.62										

NOTE: concentrations in p.p.m. unless otherwise noted.

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PROJECT 84-96 TABLE ___ SHEET 9

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well # 5 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	1690										
pH	7.05										
ALKALINITY ($CaCO_3$)	542										
ALKALINITY (HCO_3)	661										
HARDNESS ($CaCO_3$)	785										
CHLORIDES (Cl)	73										
SULPHATE (SO_4)	360										
PHOSPHORUS (TOTAL)	1.1										
TOTAL KJELDAHL	3.3										
AMMONIA (NH_3-N)	2.6										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1650										
RESIDUE FILTERED	1220										
RESIDUE NON FILTERED	430										
COD	55										
TOC	73										
TURBIDITY (NTU)	175										
POTASSIUM (K)	<5.0										
MAGNESIUM (Mg)	78.6										
CALCIUM (Ca)	185										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ____ SHEET 10

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #5 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	84.6										
IRON (Fe)	27.6										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.011										
CADMIUM (Cd)	<.001										
COPPER (Cu)	0.04										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.10										
ZINC (Zn)	0.04										
CHROMIUM (Cr)	0.009										
MANGANESE (Mn)	3.55										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ____ SHEET 11

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #6 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	1580										
pH (units)	7.10										
ALKALINITY ($CaCO_3$)	410										
ALKALINITY (HCO_3)	600										
HARDNESS ($CaCO_3$)	641										
CHLORIDES (Cl)	88										
SULPHATE (SO_4)	460										
PHOSPHORUS (TOTAL)	1.3										
TOTAL KJELDAHL	5.9										
AMMONIA (NH_3-N)	5.2										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1290										
RESIDUE FILTERED	1110										
RESIDUE NON FILTERED	180										
COD	36										
TOC	11.5										
TURBIDITY (NTU)	200										
POTASSIUM (K)	18.5										
MAGNESIUM (Mg)	69.1										
CALCIUM (Ca)	143										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ____ SHEET 12

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #6 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	90.7										
IRON (Fe)	27.7										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.036										
CADMIUM (Cd)	<.001										
COPPER (Cu)	<.01										
LEAD (Pb)	<.005										
NICKEL (Ni)	<.005										
ZINC (Zn)	<.01										
CHROMIUM (Cr)	0.006										
MANGANESE (Mn)	1.87										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ____ SHEET 13

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well # 7 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	2270										
pH	7.15										
ALKALINITY ($CaCO_3$)	838										
ALKALINITY (HCO_3)	1020										
HARDNESS ($CaCO_3$)	915										
CHLORIDES (Cl)	210										
SULPHATE (SO_4)	220										
PHOSPHORUS (TOTAL)	1.9										
TOTAL KJELDAHL	9.3										
AMMONIA (NH_3-N)	7.6										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1660										
RESIDUE FILTERED	1430										
RESIDUE NON FILTERED	240										
COD	69										
TOC	21.5										
TURBIDITY (NTU)	175										
POTASSIUM (K)	15.0										
MAGNESIUM (Mg)	97.6										
CALCIUM (Ca)	206										

NOTE: concentrations in p.p.m. unless otherwise noted.

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WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #7 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	128										
IRON (Fe)	31.5										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.118										
CADMIUM (Cd)	0.001										
COPPER (Cu)	<.01										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.01										
ZINC (Zn)	<.01										
CHROMIUM (Cr)	0.009										
MANGANESE (Mn)	2.75										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ____ SHEET 15

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well #8 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	1320										
pH	7.10										
ALKALINITY ($CaCO_3$)	622										
ALKALINITY (HCO_3)	759										
HARDNESS ($CaCO_3$)	655										
CHLORIDES (Cl)	30										
SULPHATE (SO_4)	120										
PHOSPHORUS (TOTAL)	1.0										
TOTAL KJELDAHL	5.0										
AMMONIA (NH_3-N)	4.1										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1340										
RESIDUE FILTERED	880										
RESIDUE NON FILTERED	450										
COD	47										
TOC	105										
TURBIDITY (NTU)	175										
POTASSIUM (K)	38.5										
MAGNESIUM (Mg)	57.9										
CALCIUM (Ca)	167										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE SHEET 16

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well # 8 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov. 20 1984										
SODIUM (Na)	31.7										
IRON (Fe)	20.1										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.01										
CADMIUM (Cd)	<.001										
COPPER (Cu)	<.01										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.005										
ZINC (Zn)	<.01										
CHROMIUM (Cr)	<.005										
MANGANESE (Mn)	3.87										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ____ SHEET 17

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well # 9 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
CONDUCTIVITY (umho's/cm)	1020										
pH	7.25										
ALKALINITY ($CaCO_3$)	462										
ALKALINITY (HCO_3)	564										
HARDNESS ($CaCO_3$)	509										
CHLORIDES (Cl)	27										
SULPHATE (SO_4)	105										
PHOSPHORUS (TOTAL)	0.5										
TOTAL KJELDAHL	1.2										
AMMONIA (NH_3-N)	0.48										
TOTAL NITRITE-NITRATE	<.01										
RESIDUE TOTAL	1050										
RESIDUE FILTERED	630										
RESIDUE NON FILTERED	410										
COD	34										
TOC	55.5										
TURBIDITY (NTU)	100										
POTASSIUM (K)	9.0										
MAGNESIUM (Mg)	49.8										
CALCIUM (Ca)	122										

NOTE: concentrations in p.p.m. unless otherwise noted.

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TABLE ___ SHEET 18

WATER ANALYSIS RESULTS

SAMPLING LOCATION Portage La Prairie Test Well # 9 TESTED BY W. M. Ward Technical Services Lab.

PROPERTY \ DATE	Nov.20 1984										
SODIUM (Na)	51.5										
IRON (Fe)	13.4										
CYANIDE (CN)(FREE)	<.02										
ARSENIC (As)	0.42										
CADMIUM (Cd)	<.001										
COPPER (Cu)	004										
LEAD (Pb)	<.005										
NICKEL (Ni)	0.006										
ZINC (Zn)	0.02										
CHROMIUM (Cr)	0.008										
MANGANESE (Mn)	1.65										

NOTE: concentrations in p.p.m. unless otherwise noted.

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